THE EFFECTS OF MANIPULATING ONE REQUIREMENT OF A CONJUNCTIVE SCHEDULE ON RESPONDING IN THE PIGEON

An abstract of a thesis by
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The problem. The primary purpose of the present study was to examine the effects of systematically increasing the ratio requirement of a conjunctive fixed-interval fixed-ratio schedule on responding during the fixed interval.

Procedure. Three experimentally-naive homing pigeons initially trained to peck a red response key on a fixed-interval schedule (FI 180 sec) served as subjects. The interreinforcer response range was determined for each subject on the fixed-interval schedule. The ratio values used on the subsequent conjunctive schedules were selected from each subject's baseline response distribution.

Findings. The frequency distributions of responses within each fixed interval did not systematically vary in shape as the fixed-ratio requirement was added to the fixed-interval schedule. These results were consistent across all three subjects. Subjects responded in a fixed-interval scallop on all schedules. The overall rate of responding was maintained across conditions.

Conclusions. These results suggest that maintenance of responding on a conjunctive fixed-interval fixed-ratio schedule is dependent upon the selection of the ratio values from each subject's range of interreinforcer responses on the fixed-interval schedule. Systematic selection of the ratio requirement on this schedule appears to influence the pattern of responding observed per reinforcer.

Recommendations. Maintenance of the overall response rate and fixed-interval patterning appear to depend on the manner in which the added response requirement is introduced to the subject. In order to gain an understanding of schedule-controlled behavior, researchers should carefully examine the method of response requirement selection when utilizing schedules with interval and ratio requirements.

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TABLE OF CONTENTS

APPENDIX A

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

On a simple fixed-ratio schedule of reinforcement, a fixed number of responses must be emitted by the organism before a reinforcer is delivered. Extremely high response rates are generated by this schedule, presumably because the frequency of reinforcement is based solely on completion of the response requirement. On a fixed-interval schedule, a reinforcer is delivered following the first response the organism emits after the interval has elapsed. Although only one response is required on a fixed-interval schedule, typically animals emit many responses during the interval. Response rates generated on fixed-interval schedules are somewhat lower than rates observed on fixed-ratio schedules. Fixed-ratio and fixed-interval requirements can be combined on complex schedules such as a conjunctive fixed-interval fixed-ratio schedule. On this schedule, a reinforcer is delivered upon the passage of the fixed interval of time and the completion of the ratio requirement, provided that at least one response occurs after the duration of the interval. The organism needn't complete the requirements in any particular order but can complete them concurrently.

The purpose of the present study was to investigate the effects of systematically increasing the ratio require-

ment of a conjunctive fixed-interval fixed-ratio schedule on responding during the fixed interval. One might predict that adding a fixed-ratio requirement to a fixed-interval schedule would lead to an increase in or maintenance of response rate. Paradoxically, it has been shown (Herrnstein & Morse, 1958) that as the ratio requirement increases, response rate decreases. Thus, even though this schedule has the features of both fixed-interval and fixed-ratio schedules, it maintains fewer responses than either of these two schedules programmed individually. Herrnstein and Morse (1958) initially trained their subjects on an FI 15 min schedule of reinforcement. They added a fixed-ratio requirement to obtain a conjunctive schedule. The fixed-ratio values they used were FR 10, 40, 120, and 240. Their results showed a marked decrease in responding for one subject on the Conj FI 15 FR 120 schedule and a decrease in responding for both subjects on the Conj FI 15 FR 240 schedule. One of their subjects showed a decrease in responding when the FR 10 requirement was added. Herrnstein and Morse (1958) concluded that responding on a fixed-interval schedule is altered when a restriction is placed on the minimum number of responses allowed per fixed interval. As a ratio requirement is added to a fixed-interval schedule, the minimum number of interreinforcer responses allowed per fixed interval is restricted. This restriction presumably interferes with the dynamic effects present on a fixed-interval schedule. Herrnstein and Morse (1958) attri-

bute the high average response rates observed on fixed-interval schedules to a dynamic process; low rates of responding result in reinforcement which in turn leads to higher response rates. The intervals in which few responses are emitted appear to play a critical role in the overall maintenance of responding on fixed-interval schedules.

Herrnstein and Morse's (1958) results are puzzling when one considers the possible ways that a subject could respond on a conjunctive fixed-interval fixed-ratio schedule. If the subject always completes the ratio requirement during the interval, thus never coming into direct contact with the ratio restriction, the added requirement should have no effect on responding. If the subject pauses for the length of the interval and then completes the ratio requirement, the conjunctive schedule functionally becomes a tandem fixed-interval fixed-ratio schedule. Typically, tandem schedules with fixed-ratio requirements generate a high rate of responding (Ferster & Skinner, 1958). Thus, if the subject pauses for the length of the interval on the conjunctive fixed-interval fixed-ratio schedule, responding should increase. With the preceding analysis, one would still predict no decrease in responding if the subject completed the ratio requirement during the interval sometimes and after the interval at other times.

The ratio values which Herrnstein and Morse (1958) used, however, were not systematically selected from each subject's behavior. There was a large increase in the response require-

ment for the subject when the schedule changed from the Conj FI 15 FR 40 to the Conj FI 15 FR 120 schedule, and an even larger increase from the Conj FI 15 FR 120 to the Conj FI 15 FR 240 schedule. On a simple fixed-ratio schedule, if the response requirement is abruptly increased, responding deteriorates. Responding may decrease to the point where the ratio requirement is not completed and no reinforcer is delivered. This phenomenon is referred to as ratio strain. Perhaps one of the reasons Herrnstein and Morse's (1958) results showed such a decrease in responding is that the subjects were showing the effects of ratio strain. As the ratio values used in their study were not based on the subjects' behavior, this seems to be a possible explanation. Whether the decrease in responding Herrnstein and Morse (1958) observed was due to the ratio restriction added to the interval requirement or to ratio strain has not been determined. Given the paradoxical results obtained by Herrnstein and Morse (1958), it is important that the conjunctive fixed-interval fixed-ratio schedule of reinforcement be reexamined.

The primary purpose of the present study was to examine the effects of systematically increasing the ratio requirement on a conjunctive fixed-interval fixed-ratio schedule on responding during the fixed interval. Studies examining conjunctive schedules have focused on collecting mean data, and have examined changes in patterning through the inspection of cumulative records. In order to gain a thorough understanding

of schedule-controlled behavior on the conjunctive fixed-interval fixed-ratio schedule, it is imperative that one look at changes in the distribution of responses completed within the fixed interval as the ratio requirement is systematically manipulated. In the present study, with the systematic selection of ratio values, it was expected that the overall responding during experimental sessions would be maintained or increase as the ratio requirement increased. In addition to using a shorter fixed-interval value, the present study utilized three subjects rather than two and included a stability criterion for each schedule to facilitate analysis of the results.

CHAPTER II

METHOD

Subjects

Three experimentally-naive homing pigeons maintained at 75% to 80% of their free-feeding weights served as subjects. Water and grit were available in the home cages at all times. Subjects Y-9 and Y-10 were female. The sex of subject Y-8 was undetermined, as was the age of each subject.

Apparatus

The single-key operant chamber used in this study was contained in a 38.6 x 39.4 x 69.8 cm Coleman ice chest. The response key was located in the center of a 24.2 x 28.6 cm panel and was transilluminated by a red light provided by an IEE one plane readout projector. The food magazine (BRS/LVE) was located 4.4 cm above the wire mesh floor. During the 4 sec of grain presentation, the key light was darkened and the grain magazine illuminated. Standard pigeon mix was used as the reinforcer. Continuous white noise was provided by a speaker located in the lower left hand corner of the front panel. Ventilation was provided by a fan located in the back of the Coleman ice chest. The schedules used were programmed by solid-state equipment (BRS/LVE) and data were recorded by electromechanical counters, a cumulative recorder and a cumulative digital printer (Grason-Stadler Co.).

Procedure

Each subject was reduced to 75% of its free-feeding weight, magazine trained, and shaped to peck the red response key by the method of successive approximations. Over a period of ten sessions, each subject was placed on fixed-interval schedules increasing in duration until the value of FI 180 sec was reached. This fixed-interval value served as the fixed-interval requirement used on all of the conjunctive fixed-interval fixed-ratio schedules. Subjects Y-8 and Y-10 received 76 days of FI 180 sec training while Y-9 received 42 days. The last six sessions of training were selected as the baseline data for each subject.

During each session, the cumulative digital printer recorded the number of responses occurring within each interval. Based on these data, a frequency distribution of the number of responses contained in each fixed interval was obtained. Since a subject rarely emitted the exact same number of responses during a 180 sec interval, responses during each session were grouped into class intervals. These class intervals had a width of twenty responses for all subjects. For example, if a subject made 18, 15 and 23 responses during three fixed intervals during a given session, the fixed intervals containing 18 and 15 responses would be recorded in the class interval of 0-20 responses, and the fixed interval containing 23 responses in the class interval of 21-40. Subjects Y-8 and Y-9 never made more than 300

responses during any fixed interval, and subject Y-10 never made more than 600 responses during any fixed interval.

To determine the lowest fixed-ratio values used on the conjunctive schedules, an interreinforcer response distribution was compiled across the six baseline FI 180 sec sessions for each subject. The absolute number of interreinforcer responses which corresponded to the percentile rank of 0.1 in the frequency distribution compiled across six sessions was used as the lowest fixed-ratio requirement.

The minimum addition of responses to the fixed-ratio requirement in changing conjunctive schedules was ten responses. Therefore, selection of the subsequent fixed-ratio values was not strictly determined by percentile rank, as absolute response increases were taken into account as well. The maximum addition was twenty responses. The actual fixed-ratio values used and their corresponding percentile ranks are presented in Table I. The conjunctive schedules were initially presented in an ascending order of ratio requirements. Two criterion were used to decide whether or not the ratio value was to be further increased. When pauses occurred so that sixty reinforcers were not delivered within four and one-half hours, and when a third or more of the reinforcers were dependent upon the completion of the ratio requirement after the interval had elapsed, no higher fixed-ratio values were added for that subject. The subject was then placed on the schedules of interest in a descending series of the ratio responses required. All

subjects were subsequently returned to the baseline FI 180 sec condition.

Termination of each session was dependent upon the delivery of sixty reinforcers, resulting in a minimum daily session length of three hours. The stability criterion for changing conditions required that the modal class interval in the interreinforcer response distribution did not vary more than one interval in either direction across six sessions. In addition, responding was judged to be stable if no consistent trend was present in the mean number of responses per session, with no more than 15% variability present across means. Each subject was on each schedule for a minimum of twenty sessions.

CHAPTER III

RESULTS

The major data of interest were the frequency distributions of responses emitted during the interval. As the fixed-ratio values increased to a certain value for each subject, session length increased and a third or more of the reinforcers per session were delivered by completion of the ratio requirement after the interval had elapsed. In spite of this, no systematic shift was observed in the distribution of responses completed during the interval. Subjects continued to respond in a typical fixed-interval scallop on all schedules. The overall responding during experimental sessions was maintained on all conjunctive schedules.

Table I indicates the order of schedule presentation for each subject, the number of sessions on each schedule, and the percentile rank of each fixed-ratio value used. Subject Y-10 was on three ascending conjunctive schedules. Subject Y-8 tolerated five ratio increases whereas Y-9 tolerated six different schedules before pausing began to occur. Individual differences become apparent when one compares the percentile ranks which correspond to the largest fixed-ratio values used for subjects Y-8 and Y-10. Subject Y-8's largest ratio value was FR 70 whereas subject Y-10's largest value was FR 120. Although the ratio value used for subject Y-10 was a larger ratio requirement than the one selected for

Table I. Sequence of experimental conditions, percentile rank of each FR value and number of sessions on each schedule.

Subject	Schedule	Sessions	Percentile Rank of FR value
Y-10	FI 180 sec	76	-------
	Conj FI 180 FR 80	30	0.3
	Conj FI 180 FR 100	34	1.7
	Conj FI 180 FR 120	35	3.0
	Conj FI 180 FR 100	20	1.7
	Conj FI 180 FR 80	42	0.3
	FI 180 sec	35	-------
Y-8	FI 180 sec	76	-------
	Conj FI 180 FR 10	20	1.1
	Conj FI 180 FR 30	20	3.8
	Conj FI 180 FR 40	20	6.4
	Conj FI 180 FR 50	20	14.2
	Conj FI 180 FR 70	25	40.8
	Conj FI 180 FR 50	24	14.2
	Conj FI 180 FR 30	34	3.8
	Conj FI 180 FR 10	23	1.1
	FI 180 sec	35	-------
Y-9	FI 180 sec	36	-------
	Conj FI 180 FR 40	30	1.6
	Conj FI 180 FR 50	41	2.2
	Conj FI 180 FR 60	20	5.0
	Conj FI 180 FR 70	24	10.5
	Conj FI 180 FR 80	33	19.2
	Conj FI 180 FR 90	28	35.5
	Conj FI 180 FR 60	21	5.0
	FI 180 sec	25	-------

Y-8, it represents a substantially lower percentile rank value, as drawn from the baseline fixed-interval responding. Subject Y-10's range of interreinforcer responses was much larger than the range observed for the other two subjects.

Figure 1 shows frequency distributions of responses within each fixed interval for subject Y-8. These distributions represent only the ascending series of conjunctive schedules. Each distribution represents the last six sessions on that particular schedule. As the ratio value was increased, the modal response category was not systematically affected. However, there was an increase in the frequency of intervals containing fewer responses than the modal response category as the ratio requirement increased. Likewise, there was a decrease in the frequency of intervals containing more responses than the modal response category as the ratio requirement increased. The schedules to which Y-8 was exposed in a descending series are shown in Figure 2. Again, no systematic shift in responding within each fixed interval was observed, and the distributions differ little from the primary data displayed in Figure 1. The recovery distribution for the baseline FI 180 sec schedule demonstrates a slightly more restricted interreinforcer response range than that observed on the initial FI 180 sec schedule shown in Figure 1.

The consistency of the shape of the frequency distributions across schedules is supported by the mean data presented in Figure 3. The mean number of responses completed

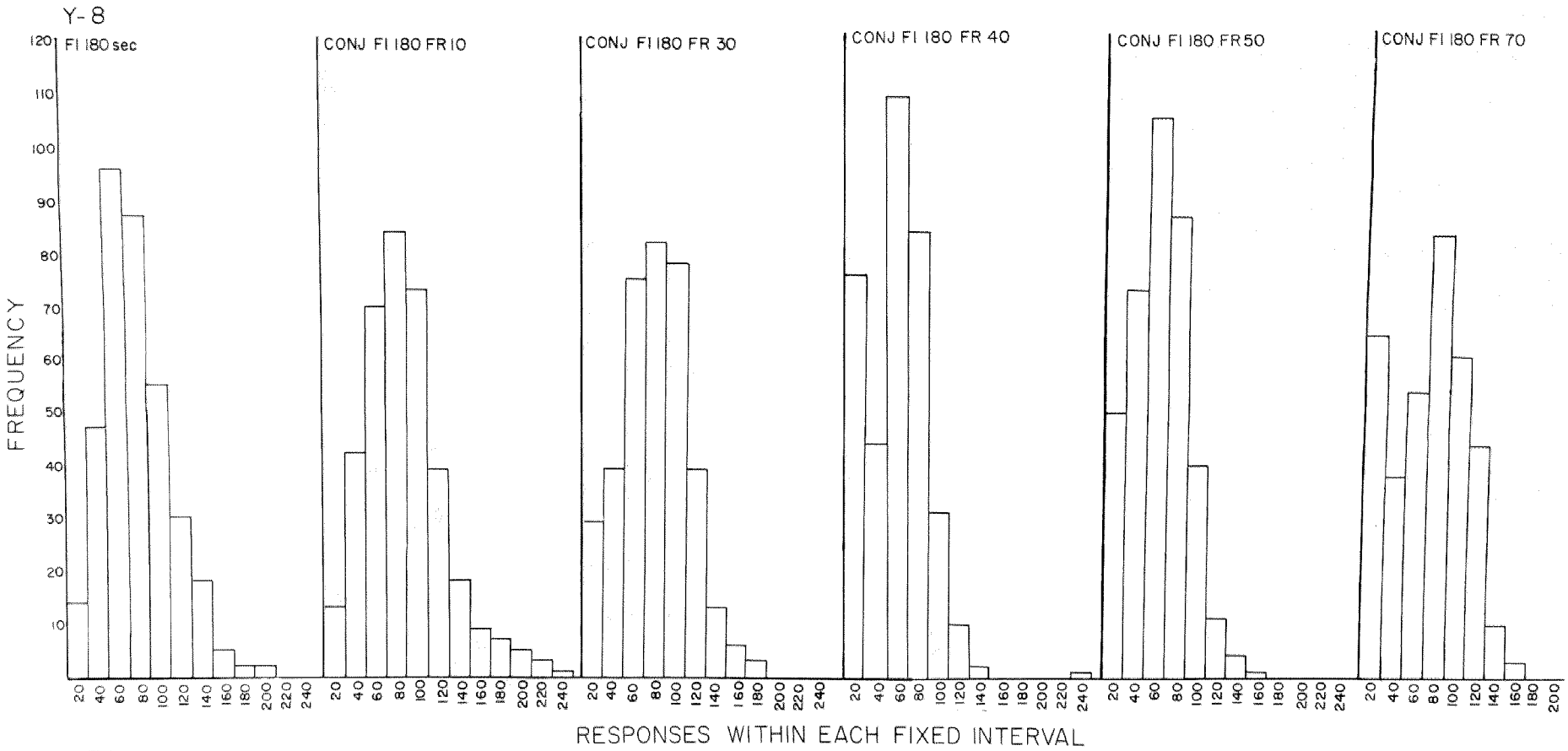

Fig. 1. Frequency distributions for subject Y-8 depicting the responses completed within each fixed interval. Data were compiled across the last six sessions on each schedule.

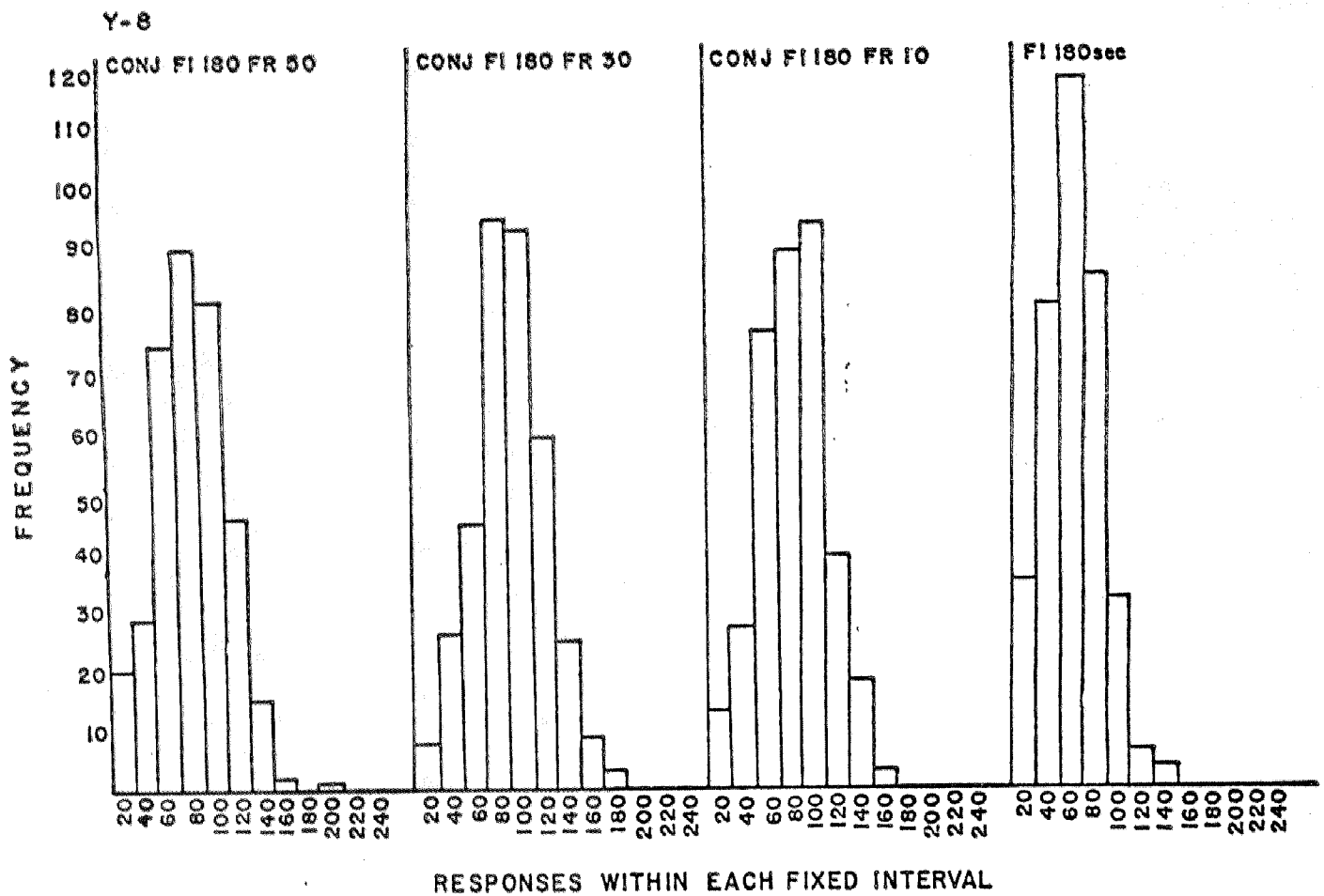

Fig. 2. Recovery data for subject Y-8. Frequency distributions represent the responses completed within each fixed interval.

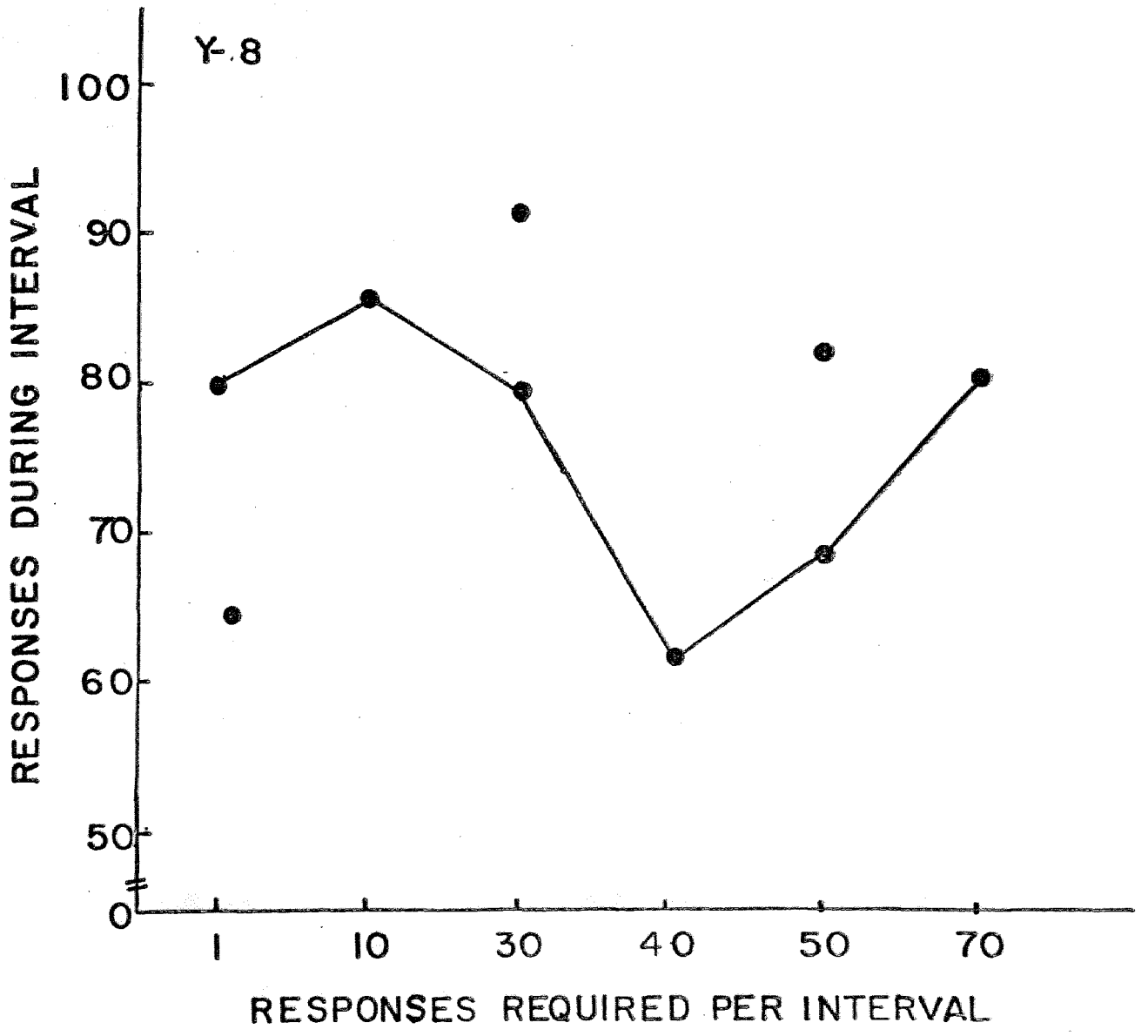

Fig. 3. Mean number of responses completed during the FI 180 sec requirement as a function of the number of responses required per interval for subject Y-8. Each data point represents the last six sessions on that schedule. Recovery data are represented by the unconnected points.

during the interval over the last six sessions on each schedule did not differ across schedules. A slightly lower mean was observed on the Conj FI 180 FR 40 schedule, and this corresponds to the increase in the frequency of intervals containing fewer responses than the modal response category observed on the three preceding schedules, as is shown in Figure 1.

Figure 4 demonstrates the frequency distribution data for subject Y-9. In comparing the distribution of responses within each fixed interval on the baseline FI 180 sec schedule with the distribution obtained on the Conj FI 180 FR 40 schedule, a substantial increase in the frequency of intervals containing less than 40 responses can be observed, as well as a shift in the modal response category towards fewer responses completed during the interval. However, the four subsequent conjunctive schedules demonstrate a return to the same type of distribution observed on the baseline FI 180 sec schedule. On the Conj FI 180 FR 90 schedule, there is an increase in the frequency of intervals containing fewer than 100 responses which corresponds to the increase in session length observed on this schedule. Figure 5 indicates the mean number of responses completed during the interval across the last six sessions on each schedule. A decrease in the mean number of responses can be observed on the Conj FI 180 FR 40 schedule, but overall responding is recovered and maintained on the subsequent schedules. The lower number of responses observed when

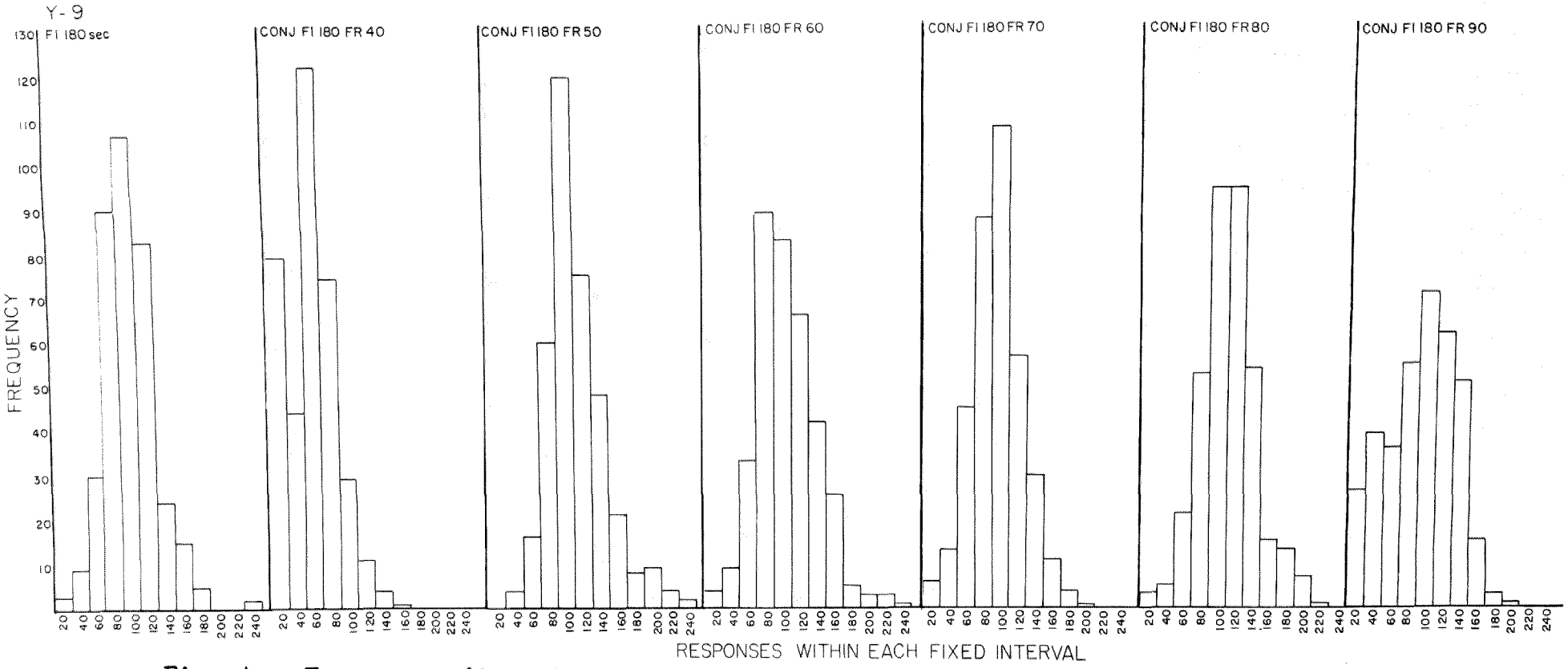

Fig. 4. Frequency distributions for subject Y-9 depicting the responses completed within each fixed interval. Data were compiled across the last six sessions on each schedule.

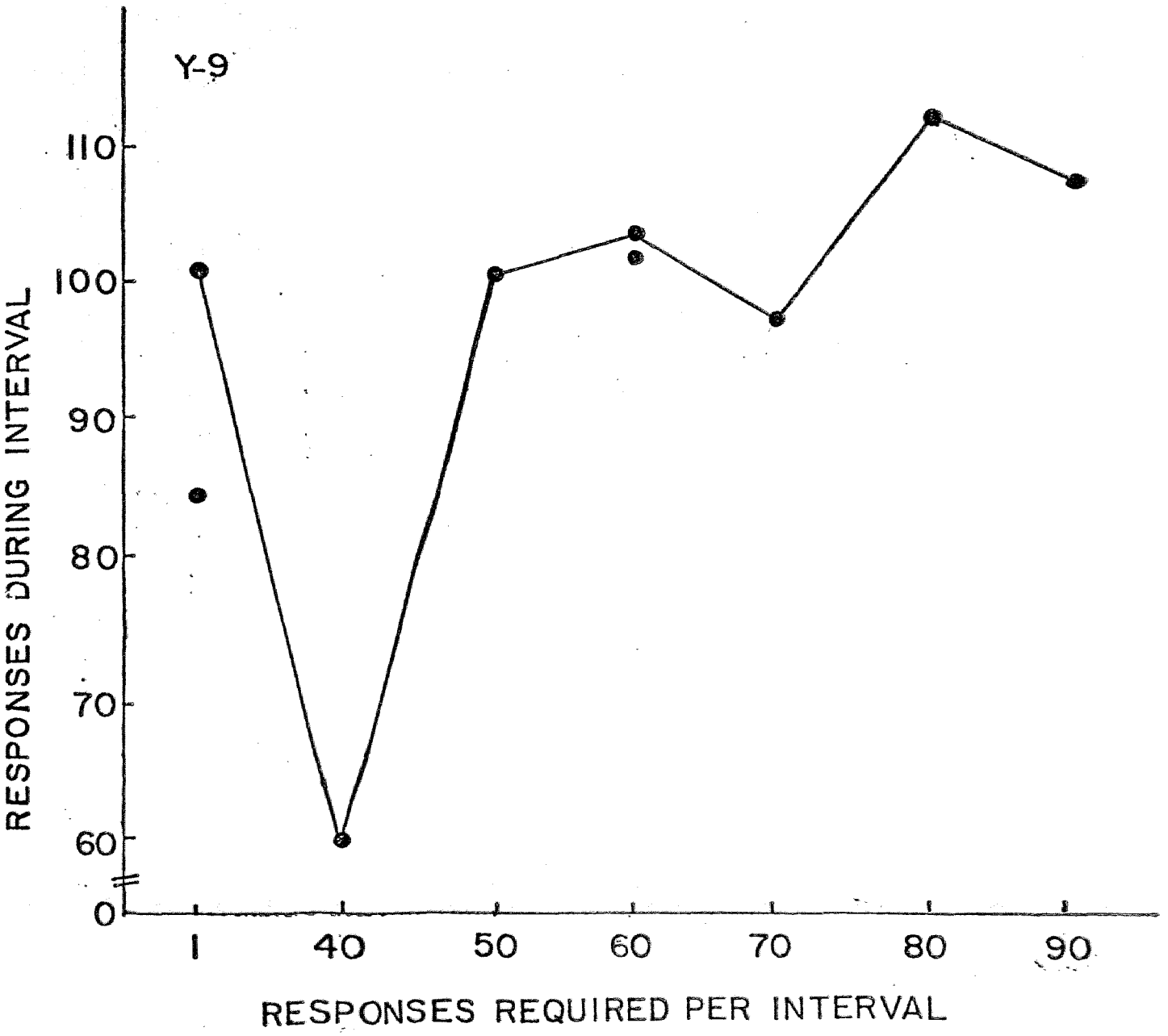

Fig. 5. Mean number of responses completed during the FI 180 sec requirement as a function of the number of responses required per interval for subject Y-9. Each data point represents the last six sessions on that schedule. Recovery data are represented by the unconnected points.

the FR 40 requirement is added can be observed in Figure 4 as well, where the number of responses completed within each fixed interval are represented. The recovery distributions for subject Y-9 are depicted in Figure 6. These distributions differ little from the primary data presented in Figure 4.

Figure 7 shows the frequency distributions of responses within each fixed interval for subject Y-10. No systematic shift in the modal response category was observed as the ratio requirement was added. On the first schedule after baseline training, Conj FI 180 FR 80, an increase in the range of responding was observed as well as a shift towards a higher modal response category. This result corresponds with the increase in the mean number of responses completed within each interval over responding on the FI 180 sec schedule, as is shown in Figure 8. On the Conj FI 180 FR 120 schedule, the range of responding within each fixed interval decreased, and more responses fell into the categories below the modal response category than at the other extreme. Consequently, the mean number of responses completed within the fixed interval also decrease, as is shown in Figure 8. The recovery data are presented in Figure 9 for this subject. The large number of responses completed within each fixed interval and the high modal response category observed on the Conj FI 180 FR 80 schedule in Figure 7 was recovered and is demonstrated in Figure 9. The distribution of responses emitted on the Conj FI 180 FR 100 shown in Figure 9 strongly resembles the distribution obtained on

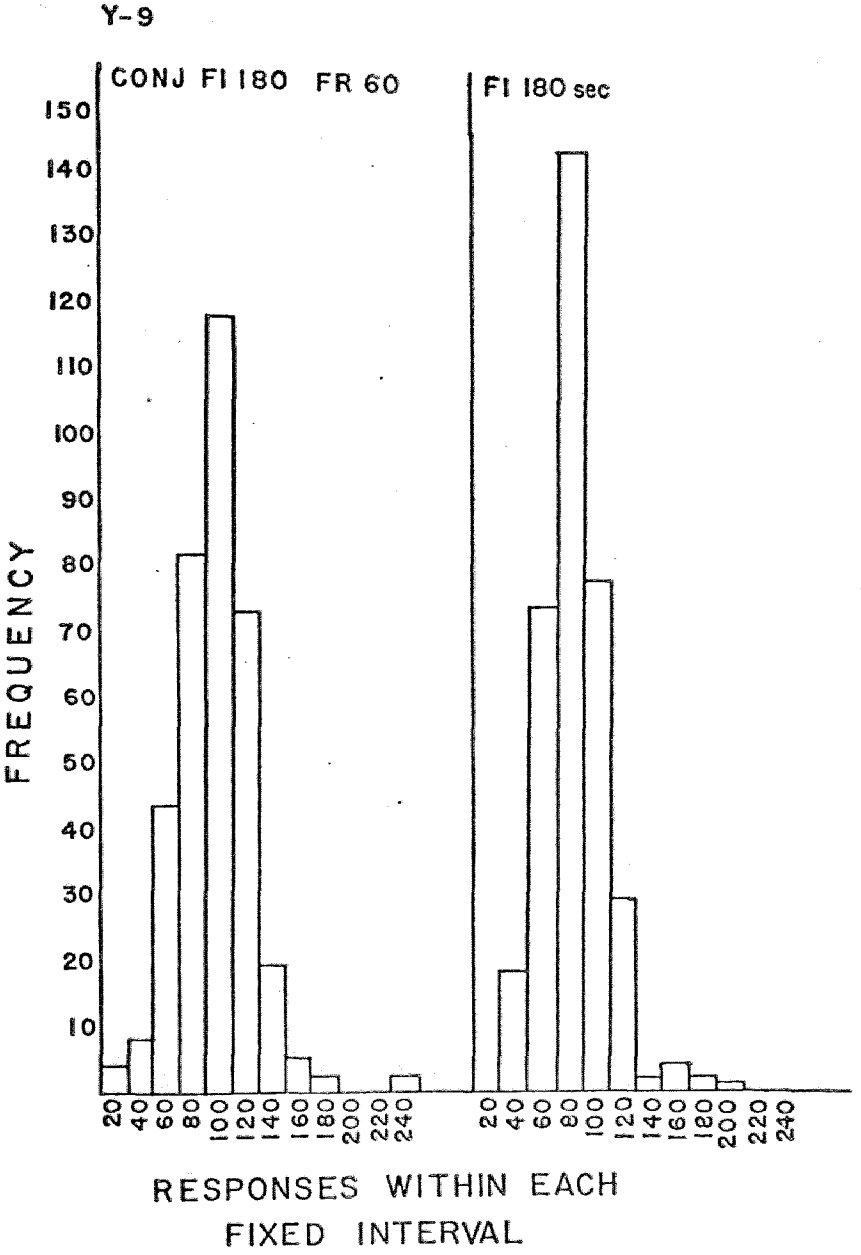

Fig. 6. Recovery data for subject Y-9. Frequency distributions represent the responses completed within each fixed interval.

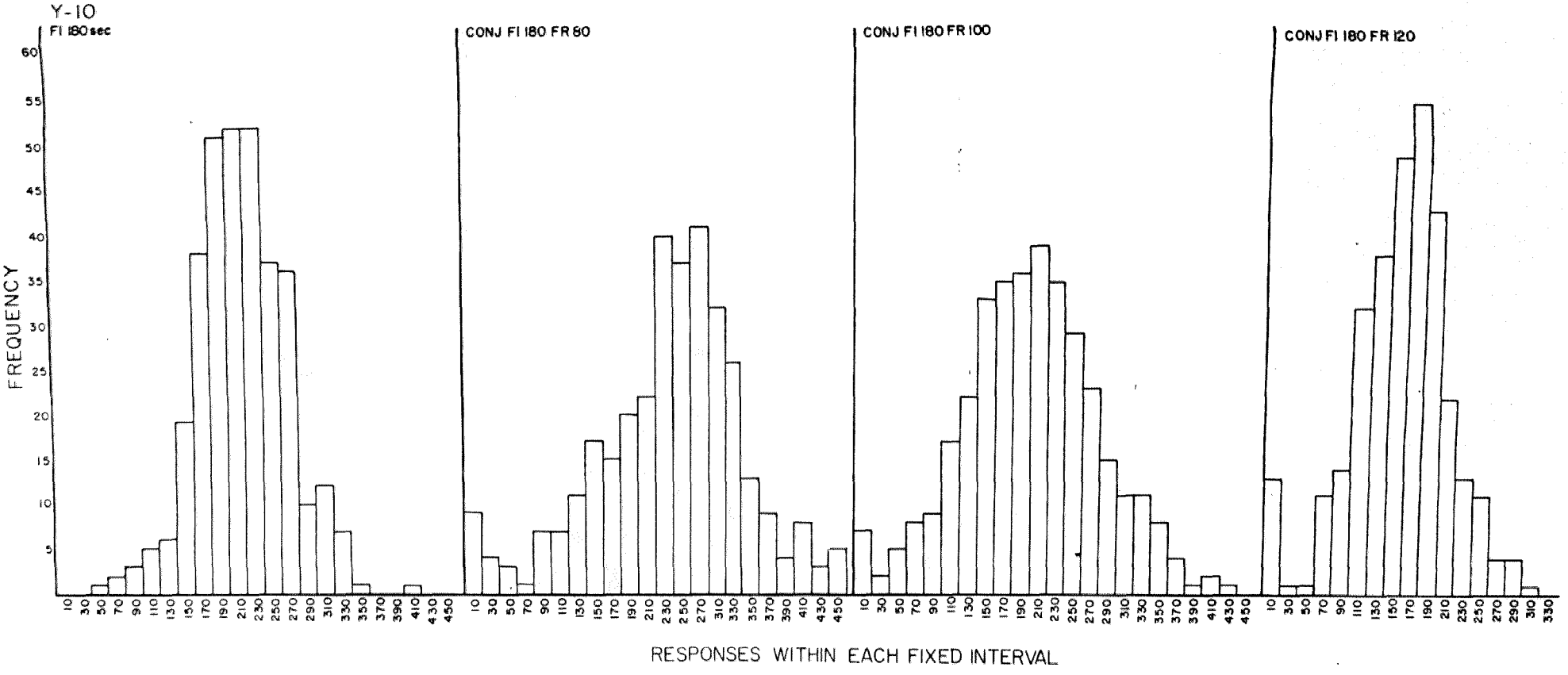

Fig. 7. Frequency distributions for subject Y-10 depicting the responses completed within each fixed interval. Data were compiled across the last six sessions on each schedule.

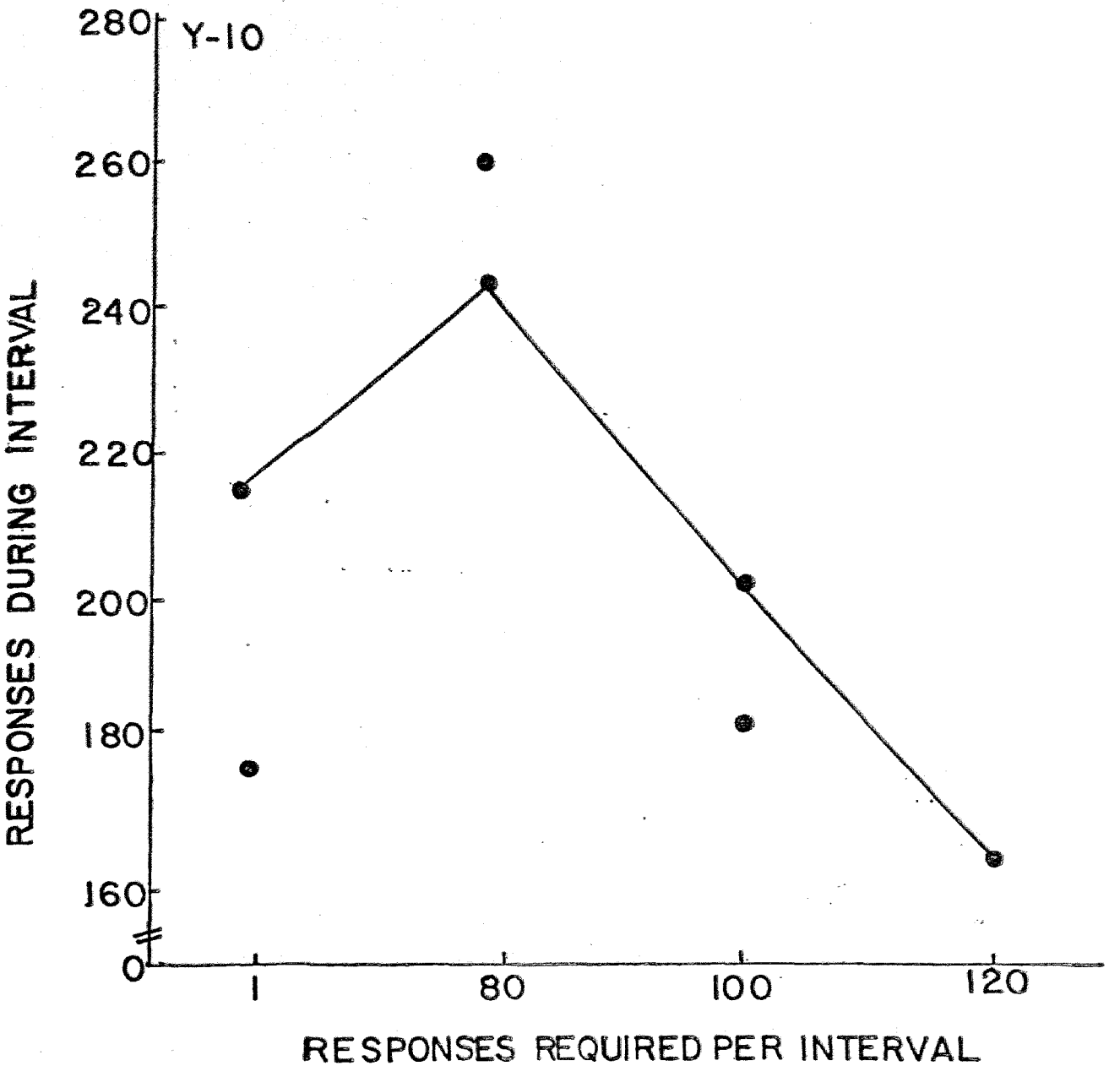

Fig. 8. Mean number of responses completed during the FI 180 sec requirement as a function of the number of responses required per interval for subject Y-10. Each data point represents the last six sessions on that schedule. Recovery data are represented by the unconnected points.

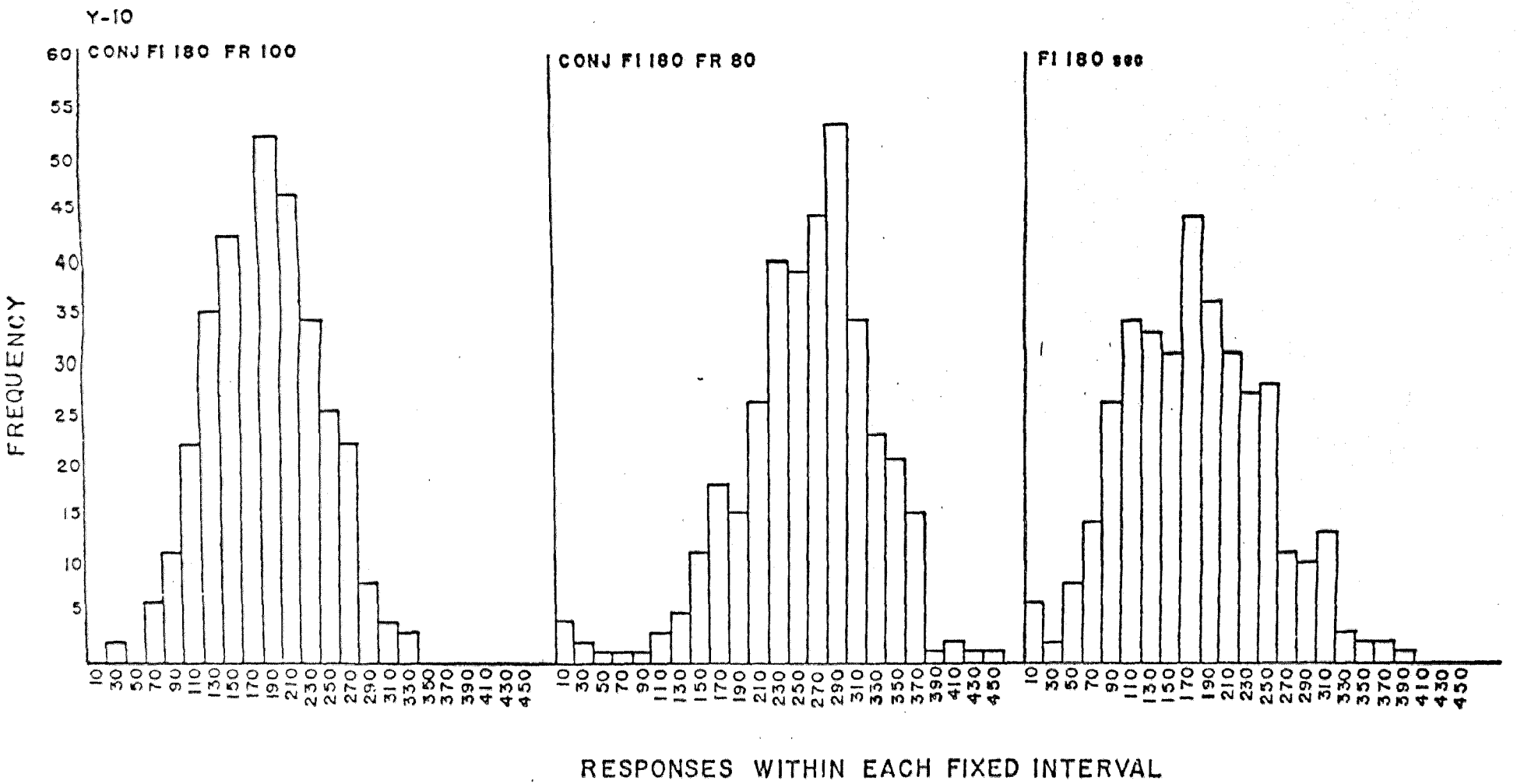

Fig. 9. Recovery data for subject Y-10. Frequency distributions represent the responses completed within each fixed interval.

the baseline FI 180 sec schedule displayed in Figure 7. The recovery of the baseline FI 180 sec schedule depicted in Figure 9 demonstrates a wider interreinforcer response range than was observed on that schedule in the ascending series. In addition, more responses occurred in the response categories below the mode than above it, as can be seen in Figure 9.

A representative sample of the cumulative response records obtained in this study is shown in Figure 10. Although subject Y-10 responded at a consistently higher rate than either Y-8 or Y-9, the basic patterning observed on the schedules was the same for all three subjects. On the baseline FI 180 sec schedule, typical fixed-interval scalloping can be observed. On the Conj FI 180 FR 80 schedule, Y-10's lowest conjunctive schedule, an increase in responding was observed, with a substantial degree of fixed-interval scalloping still present. Pausing, when it occurred, was typically at the beginning of the interval, following reinforcement. The third schedule shown in Figure 10 is the Conj FI 180 FR 120 schedule, Y-10's highest conjunctive schedule. Although longer and more regular pausing had begun to occur on this schedule, responding still occurred in a typical fixed-interval scallop. Pausing occurred at the beginning of the interval before responding had begun.

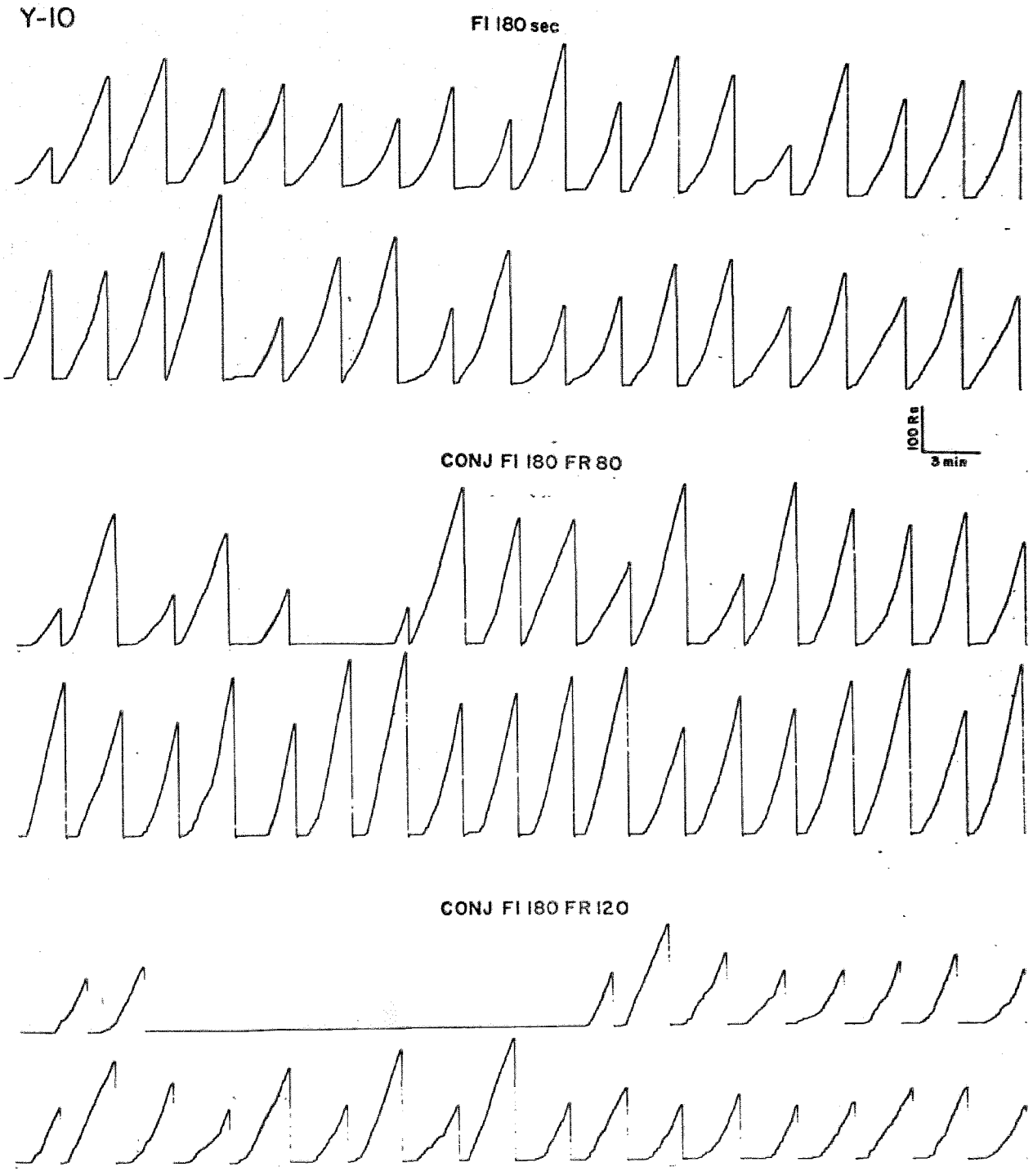

Fig. 10. Three 1 1/2 hour segments of cumulative-response records for subject Y-10. Top record represents the simple fixed-interval schedule; middle and bottom records are for the conjunctive schedules with 80 and 120 responses required, respectively.

CHAPTER IV

DISCUSSION

These results demonstrate that responding can be maintained on a conjunctive fixed-interval fixed-ratio schedule. These results suggest that maintenance of responding on a conjunctive fixed-interval fixed-ratio schedule is dependent upon the selection of the ratio values from each subject's range of interreinforcer responses on the fixed-interval schedule. The number of fixed-ratio increases tolerated by each subject before pausing during the sessions began to occur differed for all three subjects. Increasing the fixed-ratio requirement on the Conj FI 180 FR X schedule increased the session length, thus increasing the mean interreinforcer interval. Although at the higher ratio values session length increased, the distribution of responses completed during the interval did not differ appreciably from the distributions obtained on the schedules utilizing smaller ratio values.

The pattern of responding observed on conjunctive fixed-interval fixed-ratio schedules reported by Herrnstein and Morse (1958) and Barrett (1974, 1975), was different from that observed in the present study. Where Herrnstein and Morse (1958) and Barrett (1974, 1975) both observed pausing followed by fixed-ratio performance and a subsequent lower rate of responding to complete the schedule requirement, the present author did not. Instead, pausing was observed

following reinforcement at the beginning of the fixed interval, and for the most part, once the subject began responding, it would do so in a typical fixed-interval scallop. This difference in patterning may be the result of the fact that the ratio values were gradually increased in the present study, unlike the ratio requirements used by Herrnstein and Morse (1958) and Barrett (1974, 1975). The resulting pausing and fixed-ratio performances reported in those studies may have been the result of ratio strain, although there is no way to directly assess that in retrospect.

Herrnstein and Morse (1958) reported a decrease in responding for one subject when the FI 15 min schedule was changed to the Conj FI 15 FR 10 schedule. This decrease may have been due to the fluctuation in responding typically observed on fixed-interval schedules. In the present study, subjects were exposed to each condition for at least twenty experimental sessions. Prolonged exposure to each schedule allowed the subjects to come into contact with each condition and for behavior to stabilize. Subject Y-8 in the present study was exposed to a Conj FI 180 FR 10 schedule following baseline FI 180 sec training. During the first ten sessions on the conjunctive schedule, Y-8 directly interacted with the fixed-ratio requirement only twice. Given these data, it seems unlikely that the decrease which Herrnstein and Morse (1958) observed on the Conj FI 15 FR 10 schedule was due solely and directly to the added response requirement.

Hitzing and Kaye (1969) suggest that there is a basic difference between a conjunctive fixed-interval fixed-ratio schedule which utilizes a short FI requirement i.e. FI 180 sec and one which utilizes a long FI requirement i.e. FI 15 min. They observed an increase in overall response rate as they added a fixed-ratio requirement to an FI 3 min schedule. Hitzing and Kaye (1969) concluded that the differences in the results obtained in the two studies can be attributed to the difference in the length of the baseline FI schedules. The results reported in the present study confirm and extend those which were reported by Hitzing and Kaye (1969). However, it seems unlikely that the differences in responding can be attributed to the length of the FI requirement, primarily because other differences exist between the study done by Herrnstein and Morse (1958) and the studies utilizing shorter fixed-interval requirements. A more crucial difference appears to be the selection of the response requirement on the conjunctive schedules. Systematic selection of the fixed-ratio requirement, utilizing the baseline fixed-interval distribution of responding for each subject, probably plays a much more important role than the actual length of the fixed-interval requirement. Future studies which examine ratio manipulation with longer interval values are needed to clarify this issue.

In the present study, subject Y-10 demonstrated mean results similar to those reported by Herrnstein and Morse

(1958). Although Y-10 showed an increase in overall responding on the first conjunctive schedule, a subsequent decrease in responding was observed on the other two conjunctive schedules. The additional frequency distribution data collected in the present study indicates no systematic shift in the distribution of responses completed within each fixed interval, regardless of the decrease in the overall response rate. These data suggest that the subjects in Herrnstein and Morse's (1958) study may have demonstrated similar frequency distributions of responses completed within each fixed interval. Although Herrnstein and Morse (1958) assert that the pattern of responding within any interval as well as the average rate of responding per session are altered when a small number requirement is added to a fixed-interval schedule, the additional data collected in the present study do not confirm that assertion. Rather, maintenance of the overall response rate and typical fixed-interval patterning appear to depend on the manner in which the added response requirement is introduced to the subject; if the increase is systematic and corresponds to the subject's behavior on the simple fixed-interval schedule, responding will be maintained and in some cases even increase.

Eventually, at some point, responding on conjunctive fixed-interval fixed-ratio schedules does appear to decrease. This finding is consistent with Herrnstein and Morse's (1958) interpretation of what occurs on a conjunctive fixed-interval

fixed-ratio schedule. If the response requirement is not fulfilled when the time requirement is completed, a dynamic process comes into effect which is similar to the effect seen with simple high-ratio requirement schedules; the organism eventually ceases to respond. In the present study, as one third or more of the reinforcers per session were delivered upon the completion of the ratio requirement, session length did increase. This suggests that if the ratio requirement had been further increased, longer pauses and eventual cessation of responding might have been observed.

One possible explanation for this pausing, as opposed to Herrnstein and Morse's (1958) dynamic effects explanation, is that the subject begins to come under the direct control of the ratio requirement. Each time the organism pauses the duration of the interval before responding, it interacts directly with the ratio requirement. Thus, the observed pausing may be a result of ratio strain rather than some direct property of conjunctive schedules. This explanation is reasonable when one considers the fact that the organism has not been exposed to fixed-ratio training prior to its being placed on the conjunctive schedule utilizing rather high ratio values.

In examining conjunctive schedules which combine ratio and interval requirements, one must carefully consider the role which the ratio requirement plays in the obtained results. Only through examining how the two requirements in-

teract can one separate out the effects which are properties of the conjunctive schedule and those which represent direct control by the ratio or interval requirement.

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APPENDIX A

REVIEW OF THE LITERATURE

Conjunctive schedules have been examined in rats (Powers, 1968) and more extensively in pigeons (Barrett, 1974; Zeiler, 1976). Powers (1968) compared the effects of adding a time requirement to a fixed-ratio requirement on interlocking and conjunctive schedules. He found that as the temporal requirement increased on the conjunctive schedule, the overall rate decreased and the local pattern of responding was altered. This decrease did not occur with an increase in the temporal requirements on the interlocking schedule. Given the preceding analysis of how interval and ratio schedules might interact, one would predict that adding an interval requirement to a fixed-ratio schedule would lead to a decrease in responding. Powers' (1968) findings correspond to Herrnstein and Morse's (1958) results in that he obtained the same pattern of responding per reinforcer on the conjunctive schedule, consisting of both interval and ratio characteristics.

Barrett (1975) examined a conjunctive schedule with ratio, interval and fixed-time requirements. He also noted a decrease in response rates and an increase in pause duration under a conjunctive fixed-ratio fixed-interval schedule which was imposed on the subjects following either fixed-interval or fixed-ratio training. He concluded that the pattern and rate of responding on a conjunctive schedule is determined by

the combination of the individual requirements of the schedule. He also found that pigeons with prior fixed-ratio training maintained responding on a subsequent conjunctive fixed-ratio fixed-interval schedule. Those subjects displayed similar patterning to that which was observed by Herrnstein and Morse (1958). Furthermore, the rates of responding were higher for all subjects when they were placed on a fixed-interval schedule than when they were on the conjunctive fixed-ratio fixed-interval schedule.

The effects of drugs on a conjunctive schedule (Barrett, 1974), the effects of added stimulus cues (Barrett, 1975) and the effects of an adjusting requirement (Barrett, 1976) on pause length have all been examined. Barrett (1974) initially trained his subjects on an FI 5 min schedule, later adding a fixed-ratio requirement, and subsequently, pentobarbital sodium and d-amphetamine sulfate. He reported that responding on the conjunctive fixed-interval fixed-ratio schedule was similar to the responding observed by Herrnstein and Morse (1958), i.e. pausing followed by responding at a high rate and a subsequent lower rate of responding maintained until another reinforcer was delivered. The manner in which the fixed-ratio requirement was selected for the subjects was not reported in the study. Barrett (1976) also investigated performance on a conjunctive fixed-interval adjusting fixed-ratio schedule of reinforcement. He did not obtain the type of patterning previously found on conjunctive schedules which

combine ratio and interval requirements (Herrnstein & Morse, 1958; Barrett, 1974, 1975). Instead, fixed-interval scallops were noted at the lower adjusting fixed-ratio values. Barrett (1976) suggests that the typical patterning is absent because the ratio value was constantly changing, unlike the stable ratio requirements which were present in the previous studies.

Hitzing and Kaye (1969) found that responding could be maintained as well as increased on a conjunctive fixed-interval fixed-ratio schedule, a finding contrary to that of Herrnstein and Morse (1958). They also reported that no systematic change occurred in the temporal distribution of responses across schedules. One of their subjects died before the completion of the study, and the second subject ceased responding completely on the third conjunctive schedule. They suggest that using a shorter FI value than Herrnstein and Morse (1958) eliminated the critical role of intervals containing few responses in the dynamic process presumably in effect on fixed-interval schedules. Thus, adding the fixed-ratio requirement did not place the same type of restriction on the organism as it would have if the interval had been longer.

Zeiler (1976) examined the effects of a conjunctive schedule on responding which combined both response-dependent and response-independent schedules (Conj FR FT schedule). Subjects were initially trained on a fixed-time schedule, with a fixed-ratio requirement added to obtain a conjunctive schedule. His results indicated that responding came primarily

under the control of the ratio requirement on the conjunctive fixed-time fixed-ratio schedule. Zeiler references Herrnstein and Morse's (1958) study and points out that the ratio requirement in their study did not establish control over responding directly, but rather controlled responding by interfering with the dynamic effects of the fixed intervals containing few responses.